

## The Physics and Metrophysics of Unidentified Flying Objects

Reported UFO's cannot be under extraterrestrial control if the laws of physics are valid.

William Markowitz

The possibility that life exists on other planets within the solar system and other stellar systems is a question of profound interest. Conceivably, intelligent life may exist on some of these planets, and in some cases the inhabitants may be more advanced technically than we are. We assume, for purposes of discussion, that such technically advanced beings exist.

In recent years a large number of flying objects of uncertain origin have been reported. Some persons believe that these unidentified flying objects (UFO's) are controlled by extraterrestrial beings who are passengers in the spacecraft, or who may be controlling them by radio from the moon or from another planet. Others doubt this.

In a recent letter to *Science*, J. Allen Hynek urges the scientific investigation of a residue of puzzling UFO cases by physical and social scientists (1). He says there are a number of misconceptions concerning UFO reports; two of the misconceptions that he cites (with his comments) are as follows:

... UFO's are never reported by scientifically trained people. This is unequivocally false. Some of the very best, most coherent reports have come from scientifically trained people. It is true that scientists are reluctant to make a public report. They also usually request anonymity which is always granted.

... UFO's are never seen at close range and are always reported vaguely. When we speak of the body of puzzling reports, we exclude all those which fit the above description. I have in my files several hundred reports which are fine brain teasers and could easily be made the subject of profitable discussion among physical and social scientists alike.

This letter is surprising because Hynek, who has been a consultant to the U.S. Air Force for nearly 20 years, had written in the *Encyclopaedia Bri-*

tannica that there were no reports of UFO's by trained observers (2). He wrote:

U.S. air force investigators long recognized that most originators of UFO reports are sincere, interested in the welfare and security of their country and honestly puzzled by the sightings they report. Their frequent readiness to ascribe a UFO to extraterrestrial sources, their emotional attachment to this explanation and their reluctance to take into account the failure of continuous and extensive surveillance by trained observers to produce such sightings is surprising. It appears unreasonable that spacecraft should announce themselves to casual observers while craftily avoiding detection by trained observers.

I have been interested in the flight of spacecraft from the standpoint of celestial mechanics and physics for a number of years and have published a method of interstellar navigation (3). With the publication of the appeal by Hynek I decided to make a new study of the dynamics of flight and compare this with published reports and with the reports which Hynek had.

Aristotle wrote on natural phenomena under the heading "Physics" and continued with another section called "Metaphysics" or "beyond physics." I use a similar approach here. First, I consider the physics of UFO's when the laws of physics are obeyed. After that I consider the case when the laws of physics are not obeyed. The specific question to be studied is whether UFO's are under extraterrestrial control.

### Laws of Physics

The laws of physics to which I refer are those taught in any accredited college. They are the laws on which our automotive, space, and nuclear en-

gineering technologies are based. They include the laws of celestial mechanics and the laws of special relativity. Some of these laws are as follows:

- 1) Every action must have an equal and opposite reaction.
- 2) Every particle in the universe attracts every other particle with a force proportional to the product of the masses and inversely as the square of the distance.
- 3) Energy, mass, and momentum are conserved.
- 4) No material body can have a speed as great as  $c$ , the speed of light.
- 5) The maximum energy which can be obtained from a body at rest is  $E = mc^2$ .

If anyone wishes to reject these laws I have no quarrel. Let us see, however, what the consequences are if these laws are accepted.

### Possible and Impossible

Some people think that some things are impossible. This is not so. The laws of mathematics and physics, when properly applied, do provide limitations on what can be done. However, one must be careful not to state that something is impossible when he says that something is possible. It is not possible.

If we accept the properties of real numbers, Euclidean geometry, and the laws of physics, then the following statements hold:

- 1) It is impossible to construct a regular polygon of seven sides using only a straight edge and compass.
- 2) It is impossible to construct a regular polygon of seven sides using only a straight edge and compass. This was proved to be impossible by an 18-year-old schoolboy named Carl Friedrich Gauss. Incidentally, he showed that it is possible to construct a regular polygon of 17 sides, which no one had previously imagined possible.
- 3) It is impossible to construct a 2000-kilogram machine which can be driven from a starting point on top of a mountain 1000 meters (1 mile) high through the medium combustion of 0.5 kilogram of fuel.
- 4) It is impossible for a man to lift himself by his bootstraps and remain in the air.
- 5) It is impossible to construct a perpetual motion machine. This can

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has been accepted by one agency of the U.S. Government—namely, the U.S. Patent Office—which states (7):

The views of the Office are in accord with those of the scientists who have investigated the subject, and are to the effect that mechanical perpetual motion is a physical impossibility. These views can be rebutted only by the exhibition of a working model . . . [In] no instance has the requirement of the Patent Office for a working model ever been complied with . . . . Alleged inventions of perpetual motion machines are refused patents.

### Flight Principles:

#### Speed, Energy, Thrust

The principles of celestial mechanics which govern the flight of bodies under the action of gravitation were enunciated by Newton in 1687. They are still valid today for speeds that are small in comparison to the speed of light. For high speeds we must use the modifications of Einstein—that is, the equations of relativity.

The dynamics of rocket flight have been studied intensively during the past 40 years. The equations for space flight by chemical rockets, ions, nuclear engines, and photons (pressure of light), and the effects of relativity, had been derived by 1952 (8). Many of the equations are now contained in textbooks. Here I give equations without derivation.

Table 1 gives the speeds, relative energies, and times of flight for a number of hypothetical missions. The term  $E_{kg}$  is the kinetic energy per kilogram of rest mass. The round-trip time for people on the earth is  $t$ , and for people in the spacecraft,  $\tau$ .

To achieve the required speed, which can be done in steps, acceleration,  $a$ , is required. For a gravity field,

$$a = (\text{thrust} - \text{weight})/\text{mass}. \quad (1)$$

The weight term is negligible when the craft is in space, but it is important at launch. All power generated is wasted until thrust exceeds weight.

Apart from propeller and balloon action, a spacecraft can generate thrust only by expelling mass. This mass may consist of material particles, whose speed is less than that of light, or equivalent photons, which move with the speed of light. The thrust is

$$F = \dot{m}v_e. \quad (2)$$

where  $\dot{m}$  is the mass expelled per second and  $v_e$  is the exhaust speed relative to the rocket. The initial acceleration is

Table 1. Approximate speeds, relative kinetic energies, and flight times for various hypothetical flight missions.

No.	Speed	$E_{kg}$ (joules/kg)	Mission
1	8 km/sec	$3 \times 10^7$	Orbit, near earth; period, 90 min
2	15 km/sec	$8 \times 10^7$	To moon and return; $t$ , 1 week
3	20 km/sec	$2 \times 10^8$	To nearby planet and return; $t$ , 2 yr
4	100 km/sec	$5 \times 10^9$	To $\alpha$ Centauri and return; $t$ , 25,000 years
5	0.5c	$1 \times 10^{10}$	To $\alpha$ Centauri and return; $t$ , 13 yr; $\tau$ , 15 years
6	$(1-10^{-11})c$	$2 \times 10^{21}$	To Andromeda Galaxy and return; distance, $2 \times 10^6$ light years; $t$ , $4 \times 10^6$ years; $\tau$ , 18 years

small for a chemical rocket or a nuclear-powered spacecraft which expels a propellant. The acceleration increases as fuel or propellant is expelled and mass is reduced.

Let  $v$  be the speed of the rocket relative to the rest frame (the earth, effectively),  $S = v/v_e$ , and let  $R$  be the ratio of the initial to the final mass. In the absence of gravity and for  $v < c$  the following equation holds:

$$R = e^S. \quad (3)$$

The speed  $v$  can exceed  $v_e$ , but  $R$  becomes excessively large, for practical purposes, if  $S$  approaches 2. Multistaging is used to obtain values as large as 5.

To get an idea of what is required for space exploration, let us consider the Apollo spacecraft (9), shown in Fig. 1. This is designed to take three men to the moon, land two, and return all three to the earth in about 1 week. Its characteristics are as follows: height, 110 meters (364 feet); mass on launching pad,  $3 \times 10^6$  kilograms ( $6.5 \times 10^6$  pound-mass); initial thrust,  $3.3 \times 10^7$  newtons ( $7.5 \times 10^6$  pounds); initial acceleration, 0.15g; acceleration at first-stage burnout, 4g; first-stage fuel consumption, 14,000 kilograms per second for 150 seconds; exhaust speed, 2.5 kilometers per second; mass of reentry package on return to earth, 5400 kilograms.

Thus, we require about 550 kilograms on the launching pad for every kilogram which is to travel to the moon and return. This mass ratio would be enormously greater for any similar mission to a planet, even to a nearby planet such as Mars or Venus. A single Saturn V vehicle, large as it is, cannot accomplish such a mission.

Manned exploration of the planets will be very difficult with chemical rockets alone. Studies under way envisage the use of ion propulsion and nuclear engines after the spacecraft

has been removed from the path by chemical rockets.

The value of  $v_e$  obtained with chemical rockets is small, about  $8 \times 10^{-8}c$ . In theory, nuclear reactions might be used to obtain high speeds. The products of fission of  $U^{235}$  have speeds of about 0.03c. If we could obtain helium from the fusion of hydrogen, the speed of the helium would be 0.1c. The technical problem would remain: the products formed would fly in all directions.

In practice, nuclear energy can be used by heating a propellant—hydrogen, for example—and expelling it. When the propellant is gone, the rocket is dead. There is a gain over chemical rockets, and the gain makes this type of engine potentially useful for planetary exploration.

If matter and antimatter could be stored in a rocket and annihilated together, gamma-ray photons traveling with speed  $c$ , would be produced in all directions. If the radiation could be aligned and the process were 100-percent efficient, then the following equation would hold:

$$R = (1 + v/c)/(1 - v/c). \quad (4)$$

A round trip to another star would require two accelerations and two decelerations. The overall mass ratio would be  $Q = R^4$ . For  $v = 0.5c$ ,  $Q = 9$ ; for  $v = 0.9c$ ,  $Q = 361$ . If a voyage of exploration were made to three stars and back, the mass ratio would be  $R^8$ .

The thrust that would be obtained if the radiation from the annihilation of matter could be aligned is  $F = \dot{m}c$ , where  $\dot{m}$  is the annihilation rate. The power is  $P = \dot{m}c^2$ . The ratio of power to thrust is  $P/F = c$ , and  $3 \times 10^8$  watts must be generated for each newton of thrust ( $1.33 \times 10^9$  watts per pound).

To lift a spacecraft of mass 5000 kilograms (weight, 49,000 newtons) with an acceleration of 1g from the earth would require a power of about

$3 \times 10^{13}$  watts. (This is about 30 times the electrical generating capacity of the entire world.) If the  $3 \times 10^{13}$  watts were radiated from a surface of 10 square meters (108 square feet), then its surface temperature, according to the Stefan-Boltzmann law, would be about 85,000°C. Reflectors would be required to send the radiation backward, and if these absorbed even 1 percent of the radiation they would vaporize. This fundamental difficulty in interstellar flight was pointed out in 1952 by Shepherd (8, p. 408).

The possible use of interstellar matter for fuel was investigated by Pierce, and found not feasible (10).

We have assumed above that we could control mass-to-energy conversions involving fission, fusion, and an-

ihilation with equipment having negligible mass. Even if this could be done, the basic problem of aligning the motions of the particles or the radiation would remain. At the speeds involved, the particles or the radiation would interact with the atoms of the enclosure; they would not bounce back as the combustion products in a chemical rocket do.

#### Comparison between Theory and Reports

Published reports of unidentified flying objects usually describe objects seen in flight at a distance. Such sightings can give only angular diameters and angular speeds—not masses, linear

dimensions, or linear speeds. Similarly, radar measurements cannot give masses or linear dimensions. For this reason, sightings of distant flying objects are useless for comparison with the laws of physics. I do not take issue with reports of sightings and will not try to explain them away. I agree that unidentified objects exist. The question remains, however, of whether objects seen were under extraterrestrial control.

If an extraterrestrial spacecraft is to land nondestructively and then lift off it must be able to develop a thrust slightly less than its weight on landing, and twice its weight for an acceleration of 1g of lift-off. This requirement forms a critical test for comparing UFO reports with physical theory.

The published reports generally describe objects about 5 to 100 meters in diameter, which land and lift off without the use of launching pads and gantries. No similarity to the giant undertaking of a launching from Cape Kennedy has ever been reported. If nuclear energy is used to generate thrust, then searing of the ground from temperatures of 85,000°C should result, and nuclear decay products equivalent in quantity to those produced by the detonation of an atomic bomb should be detected. This has not happened. Hence, the published reports of landing and lift-offs of UFO's are not reports of spacecraft controlled by extraterrestrial beings, if the laws of physics are valid.

#### Unpublished Reports

On 20 December 1966 I wrote to Hynek, asking him for reports in his files of landings and lift-offs. He wrote that he had no reliable reports concerning landings and lift-offs. Also, he told me in a telephone conversation that he had no records of cases wherein a reliable witness visited an extraterrestrial craft or talked with an occupant. Hynek's letter to me (11) states:

To sum up my answer to your request then: the cases I mentioned in *Science* do not deal with landings or takeoffs with the possible exception of the Socorro case which is useless from a quantitative standpoint. To obtain the information you require would be a several months' job in going through 10,000 or more cases. If the Air Force had accepted my recommendation a long time ago to have all this material in machine readable form, we could in a matter of a moment or two query the tapes and bring forth all this information for you in tabular form.

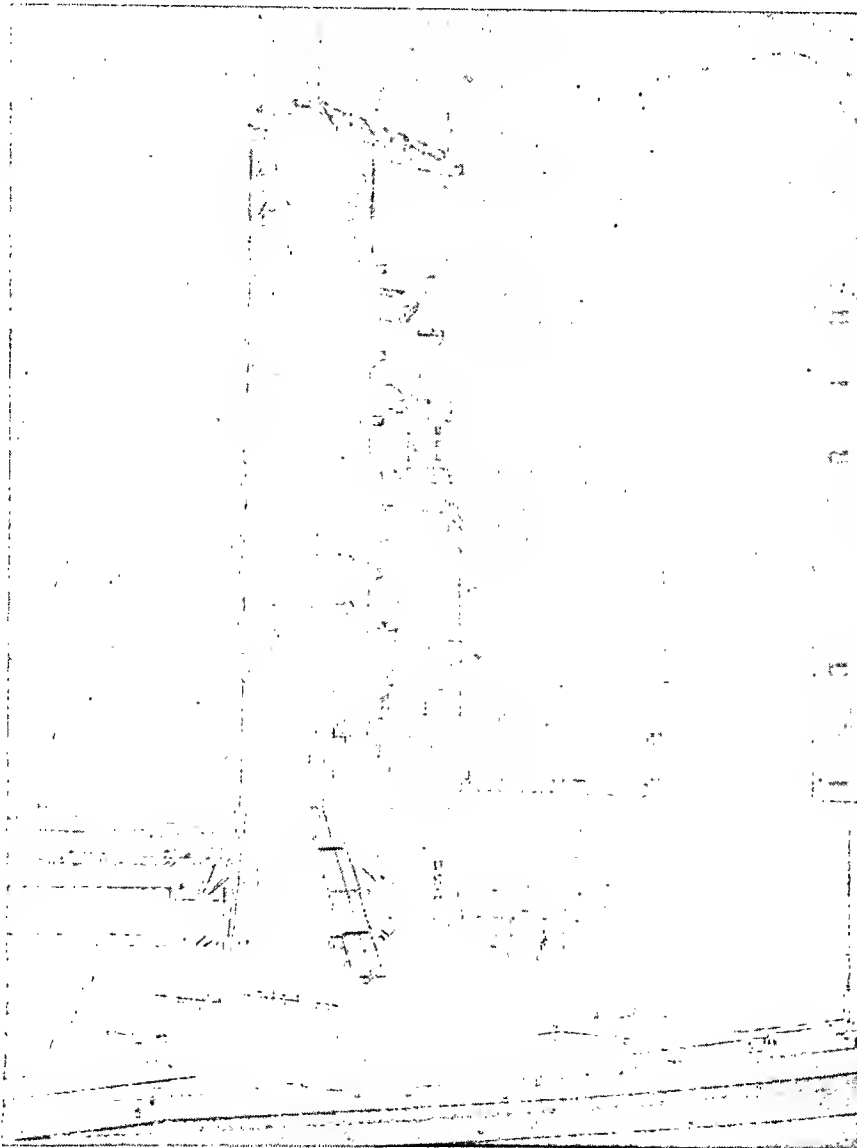


Fig. 1. Apollo Saturn 500-F test vehicle; note size of men. [NASA photograph]

The latter part of the letter is puzzling. I was not interested in the Air Force files—I was specifically interested in the cases in Hynek's files.

To check further, however, I telephoned Major Hector Quintanilla, head of Project Blue Book of the U.S. Air Force. He told me that he did not know of a single case in the U.S. Air Force files of a confirmed report of a landing and lift-off. His comments on the New Mexico case, which he released to the press, are as follows:

Conclusion: The investigators at Wright-Patterson have not been able to identify or determine what type of vehicle or object Mr. Lonnie Zamora observed on 24 April 1964 at Socorro, New Mexico. The object or vehicle displayed flight characteristics well within the State-of-the-Art and the sighting cannot be attributed to atmospheric or astronomical phenomena. In this respect, I can categorically state that the vehicle or object observed by Mr. Lonnie Zamora was not an inter-planetary space vehicle visiting the planet Earth. This case is still open and the investigation is still in progress.

#### Metaphysics

Let us now consider the possibility that the laws of physics are not valid. One idea frequently suggested is that extraterrestrial beings have discovered gravity shields. This, however, would not solve the problem of propulsion because inertia would remain; reaction would still be needed to obtain acceleration.

If we could cancel gravity on the earth, an object would lift very slowly, (i) because of the buoyancy of the air and (ii) because the object would begin traveling in a straight line whereas the earth would continue to revolve around the sun. In the story *The First Men in the Moon*, written by H. G. Wells about 1900, a shield was used to cancel the attraction of the earth but not that of the moon. The initial acceleration would be  $3.5 \times 10^{-6}g$ , which is not that reported for UFO's.

We can reconcile UFO reports with extraterrestrial control by assigning various magic properties to extraterrestrial beings. These include "teleportation" (the instantaneous movement of material bodies between planets and stars), the creation of "force-fields" to drive space ships, and propulsion without reaction. The last of these would permit a man to lift himself by his bootstraps. Anyone who wishes is free to accept such magic properties, but I cannot.

#### Semi-Magic

On another level are semi-magic hypotheses, which are proposed by scientists. These are based in part on sound scientific laws but include magic properties not explicitly stated. The general theme is that, through the use of nuclear energy and the time-dilation effect of relativity, everything is possible. Little attention, however, is paid to the practical difficulties of converting matter into energy and of utilizing it in a spacecraft without burning up the occupants. Physical processes are carried out with practically 100-percent efficiency, and complicated equipment never breaks down. Thus, we have been given theories to the effect that travel between galaxies is feasible, that a colony of extraterrestrial beings may be living on the back side of the moon, and that we may use planets of other stars to take care of overpopulation.

Intergalactic travel is fascinating. From row 6 of Table 1 we see that travel to the nearest external galaxy requires at least 4 million years between the sending forth of a spacecraft and its return. The speed given in Table 1 is  $v_G = 0.999\,999\,999\,99c$ . Propulsion would be achieved, it has been suggested, by drawing in interstellar hydrogen over an area of thousands of square kilometers and converting this to helium.

At speed  $v_G$  an interstellar particle of dust of diameter  $2.5 \times 10^{-6}$  meter (0.0001 inch) would meet the spacecraft with a kinetic energy of  $3 \times 10^8$  joules. (The kinetic energy of a 2000-kilogram automobile whose speed is 100 kilometers per hour is  $8 \times 10^5$  joules.) The energy of a proton which meets the spacecraft would be  $2 \times 10^{14}$  ev. Survival of the spacecraft and its occupants is unlikely.

#### Interstellar Communication

A question now under discussion is whether it is better to try to contact extraterrestrial beings by interstellar flight or by interstellar radio communication. The former seems impossible but the latter may be possible.

Whether we shall ever receive a message from intelligent beings on a planet outside our solar system depends upon the distance of the nearest civilization which is signaling. If it is within 100 light years, we may pick up signals. If the distance is greater than

1000 light years, the signal-to-noise ratio may be too small. Only one experiment for receiving signals has been made, Project Ozma (12). Although no contact was made, the experiment was valuable because information, even if negative, was obtained.

Considerable thought has been given to methods of exchanging information by radio. Ingenious methods of transmitting pictorial information have been proposed (13). The exchange of information will not be rapid, even if achieved, because of the large distances between stars. Hundreds of years might be needed for one exchange.

Much statistical work has been done on the probabilities of finding intelligent life. The mathematics is irreproachable, but we do not know whether the assumptions are valid. We do not know, for example, whether, given a suitable planet, living beings capable of transmitting radio signals are bound to evolve (14). Since we cannot compute with certainty where extraterrestrial life exists, we do not know if we shall ever communicate with planets of other stars.

#### Lack of Definite Evidence

If extraterrestrial beings are not bound by the laws of physics and do visit us, then we should expect to see them or their spacecraft. The facts are as follows:

1) No extraterrestrial spacecraft or passenger thereof has ever been presented to Congress, to any state legislature, or to any recognized scientific society in the United States.

2) No reliable report exists of anyone having talked with an extraterrestrial visitor.

3) No accident has ever occurred at landing or lift-off which has left an extraterrestrial spacecraft on the ground, despite thousands of alleged landings.

Believers in the possibility of interstellar travel have great difficulty in trying to explain why the visitors make no attempt to communicate with us after a voyage which supposedly has lasted tens, hundreds, or thousands of years. We would expect the visitors to contact us, take close-up photographs, and study us in detail before starting the long voyage home.

Hynek explains the lack of contact by asking, Why should extraterrestrial visitors try to communicate with us?

he states that we would observe, but wouldn't try to communicate with, a new species of kangaroo in Australia (15). This is not a convincing explanation. Intelligent human beings are not in the class of kangaroos. A more appropriate case is that of Columbus. When he landed in the New World he did communicate with the natives.

#### Hard-Data Cases

Calls for investigation of UFO's have been made by Hynek, director of the Dearborn Observatory of Northwestern University, and two associates, W. T. Powers and Jacques Vallee, based on "hard-data" cases. These cases are defined as reports of responsible witnesses from which sightings traceable to balloons, satellites, and meteors have been excluded. None, however, of the close-range cases in Hynek's files has been published in any scientific journal (16). The information which has been published contains inconsistencies.

An article by Hynek published recently in the *Saturday Evening Post* (15) includes four pictures of flying saucers. Three had captions, but there is no reference to or comment on these photographs in the text. The one showing purported objects in Sicily in 1954 was included in a book by Menzel and Boyd, who described it as a fake (17, p. 205 and plate VI).

In a letter to *Science* of 7 April 1967 (18), Powers mentions "our best five or six hundred reports," and says, "In 1954, over 200 reports over the whole world concerned landings of objects, many with occupants." Powers seems unaware that Hynek had already informed me that he had no reliable reports of landings.

Jacques Vallee is the author or co-author of books on flying saucers (19, 20). These do not report the cases completely. Some examples follow.

1) In describing the Chiles-Whitted case of 25 July 1948, *Challenge to Science* (20) mentions that two pilots in a DC-3 reported seeing a metallic, cigar-shaped object about 30 meters long with two rows of portholes, shining with supernatural brilliance; also, that a jet of flame from the object rocked the airplane (20, pp. 117, 119, 185). The book fails to mention that Hynek had identified the object as an undoubted meteor in his report of 30 April 1949 to the Air Force (17, p. 108). This omission is curious because

Hynek wrote a foreword to *Challenge to Science*.

2) Vallee describes the sighting of a geometric formation by Clyde Tombaugh on 20 August 1949, leaving the impression that the discoverer of Pluto had observed a flying saucer (19, p. 96; 20, p. 90). Vallee does not mention Tombaugh's statement that he regarded this as being a natural optical phenomenon, not an extraterrestrial spacecraft (17, p. 266).

3) Vallee implies that an intra-Mercurial planet (a planet whose orbit is within that of Mercury) was known to exist and had been lost by astronomers (19, p. 35; 20, p. 115). He does not mention that Simon Newcomb had found (21) that the hypothesis of its existence is not tenable.

The question at issue in the above cases is not what interpretation is correct or whether the authors accept the reports made. It is whether complete information has been given.

#### Investigations

The intense public interest in UFO's is due to the possibility that they carry extraterrestrial beings. Were it not for this fact there would be no demands for special inquiries, to be conducted by Congress or scientific panels. Unidentified flying objects have been the subject of countless articles in newspapers, magazines, and flying-saucer reviews, because of their sensational nature. The discussion of UFO's in scientific journals, however, has been almost nil. This is not because scientists are reluctant to study the phenomenon. It is because no reports of hard-data cases, detailed and documented, have been published in scientific journals. Such reports would have provided the basic material needed for study and discussion by scientists.

The search for extraterrestrial life is one of the most interesting problems of our times. Various methods of search have been proposed, including the manned and unmanned exploration of Mars. The wisdom of spending vast sums of money on such projects has been questioned (14), but at least the projects are sound; they are based on accepted principles of physics and engineering. This is not the case, however, for investigations of UFO's, because the extraterrestrial control of reported UFO's is contrary to accepted principles of physics.

Unidentified flying objects have been investigated by the U.S. Air Force and its scientific consultants for nearly 70 years, and not a single extraterrestrial spacecraft or occupant has been produced. As early as 1953 a panel headed by H. P. Robertson reported that UFO's are not a threat to the security of the United States. No hard-data cases which would justify the holding of additional investigations have been made public. This is not to say that airplane pilots, for example, have not seen strange phenomena. However, these cases could be studied through publication of reports in scientific journals.

From the material published it appears doubtful that any Air-Force-sponsored investigation will change the following conclusions:

- 1) UFO's are not under extraterrestrial control.
- 2) The laws of physics do not need revision to accommodate UFO sightings.
- 3) UFO's are not a threat to the security of the United States.

It is suggested therefore that, to save money and manpower, the U.S. Air Force should cease investigating UFO's. (Major Quintanilla raised no objections when I mentioned this suggestion.) Further studies should be left to any interested scientist or amateur. In particular, on-the-spot investigations by the Air Force should be terminated (22). This would free the Air Force from the charge of imposing secrecy. Surveillance of the skies for defense would continue.

In regard to secrecy, the charge that the U.S. Air Force is withholding information that UFO's are extraterrestrial is absurd. The prestige of announcing the existence of extraterrestrial beings would be so great that no scientist, journalist, politician, or government—whether of the United States, England, France, the U.S.S.R., or China—would hesitate for a moment to release the news. It could not be kept a secret.

#### Summary and Discussion

In response to the request made in *Science* (1), I have investigated UFO's and report as follows:

- 1) The control of reported UFO's by extraterrestrial beings is contrary to the laws of physics.
- 2) The data published do not justify the holding of investigations.

The U.S. Air Force has been able to resist pressures to declare that UFO's are under extraterrestrial control, but not pressures for the repetition of investigations. However, if the U.S. Patent Office can take a position on the feasibility of constructing perpetual motion machines, then the Air Force should be able to take a position on closing out its investigations of UFO's.

We have been reminded (1) that 21st-century science will look back on us. This is true. We, ourselves, look back on eras when many people believed in the existence of centaurs, mermaids, and fire-breathing dragons. I am afraid that 21st-century science will contemplate with wonder the fact that, in an age of science such as ours, the U.S. Air Force was required to sponsor repeated studies of UFO's.

I have no quarrel with anyone who wishes to believe that UFO's are under extraterrestrial control. As for me, I shall not believe that we have ever been visited by any extraterrestrial visi-

tor—either from the moon, from a planet of our solar system, or from any other stellar system—until I am shown such a visitor.

#### References and Notes

1. J. A. Hynek, *Science* 154, 329 (1966).
2. ———, "Unidentified flying objects," in *Encyclopaedia Britannica* (Benton, Chicago, rev. ed., 1964), vol. 22, p. 696; *Encyclopaedia Britannica* (Benton, Chicago, rev. ed. 1967), vol. 22, p. 499.
3. W. Markowitz, in *Air, Space, and Instruments*, S. Lees, Ed. (McGraw-Hill, New York 1963), pp. 201-66; the method is based on the fact that the observed time of minimum of an eclipsing binary depends upon the position of an observer in space relative to the sun.
4. Electrons given an energy of  $1 \times 10^9$  ev in an electron synchrotron should have a speed of 62c, according to Newtonian mechanics. However, from measurements of the synchrotron diameter and the frequency of the alternating field it is readily determined that the speed is nearly 1c. The speed, according to relativity theory, is  $0.999\,999\,87c$  ( $c = 3 \times 10^8$  meters per second).
5. His last name was Gauss.
6. The energy required is  $3.1 \times 10^7$  joules; combustion of 0.5 kilogram of gasoline produces energy of  $2.4 \times 10^7$  joules (1 joule = 0.74 foot-pound or  $9.5 \times 10^{-4}$  BTU).
7. *General Information Concerning Patents* (Government Printing Office, Washington, D.C., 1966), p. 3; see also U.S. Patent Office mimeographed statement POL-49 (6-11-47).
8. *Realities of Space Travel* (selected papers of British Interplanetary Society), L. R. Shepherd, Ed. (McGraw-Hill, New York, 1957); includes articles by L. R. Shepherd and A. V. Cleaver: "The atomic rocket," and L. R. Shepherd: "Interstellar flight."
9. Information about the Apollo Spacecraft was freely supplied by NASA.
10. J. R. Pierce, *Proc. I.R.E. (Radio and Engngs.)* 47, 1053 (1959).
11. Letter from J. A. Hynek, 25 Jan. 1967.
12. F. D. Drake, in *Interstellar Communication*, A. G. W. Cameron, Ed. (Benjamin, New York, 1963), p. 176. The possible causes of extraterrestrial life and problems of space travel are also discussed in various chapters.
13. B. M. Oliver, in *Interstellar Communication*, A. G. W. Cameron, Ed. (Benjamin, New York, 1963), pp. 294-305.
14. G. G. Simpson, *Science* 143, 769 (1954).
15. J. A. Hynek, *Saturday Evening Post* 1966, 17 (17 Dec., 1966).
16. Some early sightings, none at close range are reported by J. A. Hynek, *J. Opt. Soc. Amer.* 43, 311 (1953).
17. D. H. Menzel and L. G. Boyd, *The World of Flying Saucers* (Doubleday, New York, 1963).
18. W. T. Powers, *Science* 156, 11 (1967).
19. J. Vallee, *Anatomy of a Phenomenon* (Little Books, New York, 1965).
20. ——— and J. Vallee, *Challenge to Science* (Regnery, Chicago, 1966).
21. S. Newcomb, *Fundamental Constants of Astronomy* (Government Printing Office, Washington, D.C., 1895), p. 115.
22. Hynek, in the *Saturday Evening Post* 3), describes the near-hysteria which accompanies the chase of UFO's.

be farmed, and that oysters, clams, and fish can be farmed (not farmed) as an improvement over catching them in their wild state. (Note that noticeable materials such as lumber, whale oil, shells, pearls, wool, hides, and fertilizer are not included in this study.

## Human Food from Ocean and Land

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During recent years many claims have been made about the importance of the ocean to man's future well-being. Some of these claims appear to us to be reasonable, whereas others have an Alice-in-Wonderland quality. As a basis for judgment in this matter, we have compiled a table that shows our estimate of the tonnage and dollar value of food derived from the ocean as compared with that derived from the land during 1964, the latest year for which statistics are reasonably complete. The difference in the former productivity of the ocean and the land is so great as to suggest that an enormous effort will be required before the production of the ocean can be comparable with that of the land.

A sort of genetic classification of

food resources was used to compare the present stages of technology in the ocean and on the land. For plants, the primitive stage is that of gathering wild plants (on land—berries, nuts, mushrooms, herbs); the next stage is farming (whereby seed are planted and the plants are tended and then harvested). For animals, the primitive stage is that of hunting wild animals for food (on land—deer, rabbits, quail); the next stage is herding (whereby selected breeding, culling of young, and controlled slaughter are practiced along with the nondestructive taking of by-products such as eggs, milk, and wool). This terminology, gathering and farming of plants, and hunting and herding of animals, is also applied to the ocean in a strict sense. For example, we consider that only algae or bacteria can

#### Data

The production figures (Table 1) are uneven in quality. Some figures, such as those for fishing, herding, and farming are reasonably well known and have been reproduced in many publications. Others, such as for gathering and hunting on land, must be based upon judgment guided by scanty measurements. The data for the United States are far better than those for the whole world, so they are presented separately. Tonnages are expressed in wet weight or live weight as usually reported, and dollar values are for the level of the fisherman, farmer, or hunter; values at the retailer level would be much higher.

Data for the gathering of seaweed were compiled by the Battelle Institute (1), but the quantity and value of wild plants gathered from land is so poorly

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